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Dated 10 April 2003

PRIORITY DOCUMENT

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GB 0205062.3

By virtue of a direction given under Section 30 of the Patents Act 1977, the application is proceeding in the name of

INTELLIGENT DIESEL SYSTEMS LIMITED,
The Elms,
Units 5/6,
New York Mills,
Summerbridge,
HARROGATE,
United Kingdom

Incorporated in the United Kingdom,

[ADP No. 08549099001]

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uest for grant of a patent

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our reference	JCD/MK/G32369
atent application number *(The Patent Office will fill in this part)* -5 MAR 2002	**0205062.3**
'ull name, address and postcode of the or of ach applicant *(underline all surnames)*	**Autogas Supplies Limited** **The Elms** **Units 5/6, New York Mills** **Summerbridge** **Harrogate** **North Yorkshire HG3 4AL**
its ADP number *(if you know it)*	8336208001
applicant is a corporate body, give the ry/state of its incorporation	**England**
'itle of the invention	**Dual Fuel Engine**
Jame of your agent *(if you have one)*	**Bailey Walsh & Co.**
Address for service" in the United Kingdom o which all correspondence should be sent *(including the postcode)*	**5, York Place** **Leeds** **LS1 2SD**
ts ADP number *(if you know it)*	**224001**

SECTION 30(1977 ACT) APPLICATION FILED 20/1/03

f you are declaring priority from one or more arlier patent applications, give the nd the date of filing of the or of each of these arlier applications and *(if you know it)* the or ach application number	Country	Priority application number *(if you know it)*	Date of filing *(day / month / years)*

f this application is divided or otherwise lerived from an earlier UK application, ie earlier application	Number of earlier application	Date of filing *(day / month / years)*

s a statement of inventorship and of right o grant of a patent required in support of his request? *(Answer "Yes" if:* — **Yes**

) any applicant named in part 3 is not an inventor, or

) there is an inventor who is not named as an applicant, or

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Description	12
Claim(s)	
Abstract	
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Priority Documents	
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(Please specify)*	

11. I/We request the grant of a patent on the basis of this application

Signature

Date

4th March 2002

12. Name and daytime telephone number of person to contact in the United Kingdom

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Dual Fuel Engine

This invention relates to a dual fuel engine, and more specifically to a method for converting a conventional diesel engine to one which is capable receiving both diesel and a second fuel, which is most commonly liquid petroleum gas (LPG) or less commonly compressed natural gas (CNG). The invention also relates to and is to be considered as extending to a dual fuel engine which operates in a particular manner as hereinafter described.

Although the following description is provided with exclusive reference to the conversion of conventional diesel engines to engines which are capable of receiving both diesel and LPG as the main combustive fuel components, the skilled reader will appreciate that the following invention can easily be adapted to allow for conversion of conventional diesel engines to permit them to utilise a wide variety of different gases, and therefore the invention should not be considered as solely limited to diesel/LPG engines.

Dual fuel engines have been produced in the past, and indeed it has for a long time period been known that the combination of diesel fuel with LPG inside the cylinders of an engine not only can improve efficiency of the engine, but automatically reduces the overall fuel cost of the operating the engine. For example, in the UK, diesel fuel typically currently retails for around £0.76 per litre, whereas LPG can readily be obtained for around £0.23 per litre. However such cost savings must be offset against the cost of converting the diesel engine.

Currently, it is generally the case that most conventional diesel engine conversions are time consuming, elaborate and expensive. As far as the changes which are required to be made

to an engine to enable it accept both diesel and LPG fuels, as the reader will be aware, diesel engines are not provided with spark plugs as the ignition of the diesel fuel is achieved solely by pressure developed in the cylinders by virtue of the reciprocating motion of the pistons and additionally by virtue of the inherent heat of the engine during operation. It is this latter requirement for heat that necessitates a delay between initially starting the engine (which causes a heater to operate) and firing the engine, i.e. causing the driveshaft on which the pistons are mounted to rotate.

In replacing some of the diesel which is injected into the cylinders with an amount of LPG, it is necessary to remove the diesel injectors and the diesel injection pump and fit reduced capacity components in their place, change the head gasket of the engine to reduce the compression ratio achieved in the cylinders, and fit a distributor to adjust the timing of the engines. A conventional conversion, particularly for a large diesel engine such as might be provided in a locomotive or articulated lorry may cost in the region of £28,000. Of course this figure depends on the size of the engine, and in particular the number of cylinders within the engine.

Notwithstanding the expense of diesel engine conversion, the advantages in terms of fuel cost savings and efficiency characteristics achieved by conversion often outweigh the cost, and many conversions have at the present time been conducted. Indeed relevant prior art reflects this fact.

For example, US4463734 discloses a diesel-based engine which is designed to burn on a mixture of LPG and diesel. The diesel is injected into the cylinders in the conventional manner, but in addition to this, LPG in its gaseous phase is mixed with the airflow which is essential to the proper functioning of the

engine. In general, engines may be normally aspirated, in which case the air is forced into the engine simply by virtue of the forward motion of the vehicle in which the engine is mounted, or alternatively the engine may be turbocharged in which case a small turbine driven by the exhaust gases from the cylinder is linked to a compressor to compress the air within the inlet manifold before it is delivered into the engine cylinders. This results in improved performance and additionally enhances the efficiency of the engine. Regardless of the condition of the air when it is introduced into the engine, the air is essential as it provides a supply of oxygen to fuel the combustion. In the abovementioned US patent, the LPG is mixed with the incoming air so that the inlet manifold to the engine contains both a supply of oxygen and gaseous LPG. This mixture is then introduced into the cylinders of the engine in the same way that a conventional air stream would be introduced, namely through the air inlet valves of each cylinder.

As mentioned above the diesel continues to be injected into the cylinders through specifically adapted injectors provided on each cylinder.

The US patent goes on to describe how the governor of the diesel engine is coupled to an LPG regulator so that as the load on the engine increases, the percentage of total fuel delivered to each cylinder of the engine which is LPG increases significantly quicker than does that percentage of total fuel which is diesel, this latter increase being achieved under the conventional operation of the engine and not being regulated in any way by the governor. Specifically, the inventor mentioned in connection with said US Patent made the realisation that when the engine was idling or operating under very light loads the amount of diesel as expressed as a percentage of the total fuel weight (i.e. diesel and LPG) introduced into the cylinder should be relatively

high, typically in the region of 75%, whereas when the engine was operating under heavy or full load conditions, the amount of diesel expressed as a percentage of the total fuel delivered should be quite low, typically of the order of 20%. Under these parameters, the engine could operate significantly more powerfully, more efficiently, and at lower cost.

However, a fundamental disadvantage of the invention described in this patent is the predetermined nature of the operating characteristics necessitated by the direct mechanical link between the LPG regulator (which is a valve in the main embodiment) and the governor of the diesel engine. For instance, under a particular load, the governor of the engine will necessarily operate in a particular manner causing the regulator to open or close to a predetermined extent. Accordingly, the system proposed in the US Patent is inflexible.

A further disadvantage of this invention is the fact that the LPG is mixed with the incoming air flow in a plenum ring prior to entry of the air into the cylinders of the engine. This further precludes versatile operation of the engine.

It is an object of the invention to provide a dual fuel engine and management system therefor which is flexible, can be easily adapted to different types of dual fuel combinations (e.g. diesel/LPG, diesel/CNG, and diesel/other liquid or gaseous combustive material giving high combustion thermal output), and which is capable of significantly reducing the overall emissions of the engine over a wide operating profile.

According to a first aspect of the invention there is provided a dual fuel engine to which there is supplied at least diesel and one other secondary fuel, said engine comprising cylinders in which pistons reciprocate, each of said cylinders being provided

firstly with an injector through which the diesel fuel is injected into the cylinder during the appropriate stroke of the piston and secondly with an air inlet valve which opens during the appropriate stroke of the piston to permit air flow therethrough, characterised in that each cylinder of the engine is further provided with secondary fuel injectors through which the secondary fuel is injected into the cylinders, said secondary injectors being independent from the diesel fuel injectors and on the appropriate stroke of the pistons reciprocating therein.

Preferably, the engine is provided with a pair of supply tanks for containing diesel and the secondary fuel, both of which are delivered to the engine through separate supply pipes.

Preferably, the injection of the secondary fuel into the cylinders occurs simultaneously with the injection of the diesel fuel through the diesel fuel injectors.

Preferably, the secondary fuel is LPG.

It is yet further preferable that the amount of secondary fuel flowing into the engine is regulated by a flow control unit (FCU).

Most preferably the output of the FCU is coupled to the input of a multi-output divider which divides a singular flow of secondary fuel into a plurality of flows, said plurality corresponding in number to the number of cylinders in the engine and said plurality of flows being coupled to said secondary fuel injectors.

Most preferably the flow of secondary fuel to the secondary fuel injectors is regulated dynamically according a number of sensed engine operating characteristics, and most preferably the

dynamic regulation is applied to the FCU which alters the amount of secondary fuel flowing therethrough.

Most preferably the engine includes an integrated control unit (ICU) which has one or more of the following:

- a collection of inputs in communication with a number of sensors disposed in and around the engine for sensing different operating characteristics thereof,
- means capable of receiving and processing a user input
- a system calibration connector through which maintenance and adjustment of the algorithms and operating parameters of said ICU can be achieved, such as might be required for converting a diesel/LPG engine to a diesel/CNG engine
- a collection of outputs for both displaying relevant information concerning the operating characteristics of the engine, e.g. the instantaneous relative percentages of diesel and secondary fuel being delivered to the engine, and which are connected to one or more dynamically adjustable components of the engine for dynamic control thereof during engine operation.

It is still yet further preferable that the emergency shut off valves are provided in the supply pipes which deliver the diesel and secondary fuel to the engine.

In a particular embodiment, both an FCU and a vaporiser are provided in the supply pipe which delivers the secondary fuel to the engine, said ICU controlling both the FCU and a diaphragm within the vaporiser, both of which are adjusted to regulate the flow of the secondary fluid through each component.

The FCU may be provided in addition to the vaporiser to prevent any back pressure developed in the supply pipe between

the FCU and the engine as a result of back- or mis-fires thereof from destroying the diaphragm in the vaporiser unit.

It is to be mentioned that in general the FCU in the supply pipe delivering the secondary fuel to the engine is typically optional, whereas the vaporiser tends to be more essential as vaporisers are commonly provided with a heating element which is required to gasify the LPG, which is usually a liquid at the pressures (of the order of 1-3 bar above atmospheric pressure) at which LPG is usually stored.

The ICU is connected to both the FCU and the vaporiser and can cause adjustment of same, not least in adjustment of the amounts of secondary fuel permitted to flow therethrough but also as regards the temperature of the heating element therewithin. Also, the ICU may receive a feedback in terms of the vaporiser to allow said ICU to determine the temperature of the LPG exiting the vaporiser.

Most preferably the ICU is connected to a plurality of sensors adapted to sense a variety of engine operating characteristics or factors representative of such characteristics. A non-exhaustive list of examples may be:

- Emissions, in particular exhaust gas particulate measurements such as density and chemical composition
- Exhaust gas particulate density
- Throttle position
- Temperature, of both LPG being delivered to the engine and the engine operating temperature itself
- Turbo pressure
- Airflow velocity and pressure
- Secondary fuel gauge
- Engine speed

- FCU position, in particular the position of the piston inside the FCU whose position is changed to alter amount of secondary fuel permitted to flow therethrough
- Vaporiser diaphragm position

Most preferably the operation of the ICU is continuous and concomitantly the volume of secondary fuel being delivered through the engine through the vaporiser and FCU is continually and continuously being adjusted depending on the feedback from the various different engine operating characteristics being measured.

Most preferably the ICU includes a processor and associated memory in which a series of parameters for efficient engine operation are stored. The memory may RAM, ROM, PROM, EPROM, or any combination of these. Additionally, memory contains a series of algorithms implemented in suitable code which can be executed by the processor when certin trigger conditions are met, for example

- when the engine is started,
- when the secondary fuel runs out
- when the load on the engines reaches a desired level or reduces beneath a certain level.

Most preferably the ICU performs a calculation on the various values received on its inputs from the various different sensors using the algorithms stored, and the result of the calculation will usually be a value to which the vaporiser diaphragm or FCU piston must be set to achieve the most efficient or most powerful output for those particular operating conditions.

It is to be mentioned that the ICU may have been preprogrammed with a plurality of different algorithms adapted to achieve different engine responses for a given set of

operating characteristics. For example, if maximum engine power is to be delivered and little or no concern for emissions is required, then a particular algorithm or set of algorithms may be selected, whereas if minimum emissions is crucial, then a different algorithm or set thereof may be selected.

It is yet further preferable that an LPG limiter is provided to prevent any "over-powering" of the engine which would drastically reduces its operating life.

It is still yet further preferable that a recalibration algorithm is included in the ICU which enables said ICU to adjust its own operation as the engine and associated components undergo wear.

In different aspects of the invention, there are provided an ICU for controlling the operating of a dual fuel engine as hereinbefore described, and additionally there is provided a method of converting a conventional diesel engine for use as a dual fuel engine wherein the engine is provided with secondary fuel injectors in addition to the existing diesel injectors, and further in addition to the conventional air inlet provided into each of the cylinders. These aspects of the invention are to be considered as separate and independently claimable aspects of the invention.

It has been suggested by the applicant that this dynamic system can in certain circumstances increase engine power output by up to 50% and reduce noxious particulate emissions equally significantly.

A specific embodiment of the invention is now provided by way of example with reference to the accompanying diagram wherein

Figure 1 shows a schematic representation of a diesel engine converted for use as a dual fuel engine.

Referring to Figure 1, there is provided an engine 2 comprising 4 cylinders 4, 6, 8, 10 in which pistons are disposed (not shown) mounted on a drive shaft 12 by which power is delivered from the engine. Each of the cylinders is provided with a pair of injectors 4A, 4B, 6A, 6B, 8A, 8B, 10A, 10B, and air inlets 4C, 6C, 8C, 10C.

The engine is supplied with two different fuels from separate tanks 14, 16, and the fuel is delivered from these tanks to the injectors 4A, 4B, 6A, 6B, 8A, 8B, 10A, 10B via supply pipes 18, 20. Emergency shut off valves 22, 24 are disposed proximate the tanks for obvious purposes.

The tank 16 is adapted to contain slightly pressurised LPG (to liquefy same), and this LPG is delivered firstly to a vaporiser unit 26 having a heater 28 therein. A diaphragm 30 is also provided in this vaporiser. Thereafter, the LPG flows along the supply pipe to a flow control unit (FCU) 32 which can also be adjusted to alter the volume of LPG allowed to pass therethrough. From the FCU, the LPG flow enters a multi-output unit 34 which divides the flow into four separate flows which are then delivered to the LPG injectors 4B, 6B, 8B, 10B.

An air supply is provided at inlet 36, and regardless of whether normally aspirated or turbocharged, the air is also divided into four separate flows delivered to the air inlets on each cylinder.

Finally, diesel fuel is provided in tank 14 and after passing through the emergency shut off valve 22 enters a diesel pump 38 as is conventional for diesel engines, and subsequently the flow of diesel emerging therefrom is passed to a second multi-output

unit 40 whereafter four separate supplies of diesel are delivered to the diesel fuel injectors 4A, 6A, 8A, 10A.

In accordance with a particularly preferred aspect of the invention, the diesel fuel may also pass through a flow control unit 42, but this feature is optional.

In accordance with the invention, and to control the operation of the engine in a desired manner, an integrated control unit (ICU) 44 is provided. The ICU primarily acts to dynamically control the volumetric quantity of LPG delivered to the cylinders of the engine, and may also be used to control the temperature and pressure thereof also. It may also be used to dynamically control the temperature and pressure of the LPG, and although such control would be unprecedented and complex, it is certainly within the bounds of this invention.

In this regard the ICU receives a plurality of inputs and has a plurality of outputs. In particular, the ICU receives inputs/delivers outputs as follows:

- (44, input) from a gauge in the tank 16 to provide a measure of the amount of LPG remaining in said tank
- (45, input/output) to close or detect condition of emergency shut off valve 24
- (46, input/output) from the heater within the vaporiser to determine/set the LPG temperature leaving the vaporiser
- (47, input/output) from the diaphragm of the vaporiser to determine/set the position thereof
- (48, input/output) from the FCU to determine/set position of piston therein to finely adjust volumetric flow rate therethrough
- (49, input) from one or more exhaust probes 50, 51 for measuring particulate content/constitution/density of exhaust gases (one particular type of such a probe is a so-

called "lambda" probe developed and sold by Volkwagen Audi Group AG of Germany)

- (52, input) from a sensor adjacent or on the drive shaft to monitor engine speed
- (53, input/output) a service connector to allow service and other authorised personnel with suitable computer equipment to adjust the working of the ICU and upload parameters for fine tuning/calibration thereof
- (54, input/output) a connection with a User Interface comprising one or more indicator or LEDs for demonstrating

  - that the system is functioning correctly and within desired operating ranges,

  - that there is sufficient LPG in the tank,

  - that the system is operative, or for enabling the system to be switched off (in which case the engine would revert to operation as a conventional diesel engine-this is entirely possible)

As it can be seen the ICU is fundamental to this invention, and in particular it is to be mentioned that the full dynamic, continuously altering control of the volumetric quantity of LPG depending on operating conditions, and particularly dependent on a measurement of exhaust gas quality is revolutionary and has provided significant engine operating efficiency and power output benefits.

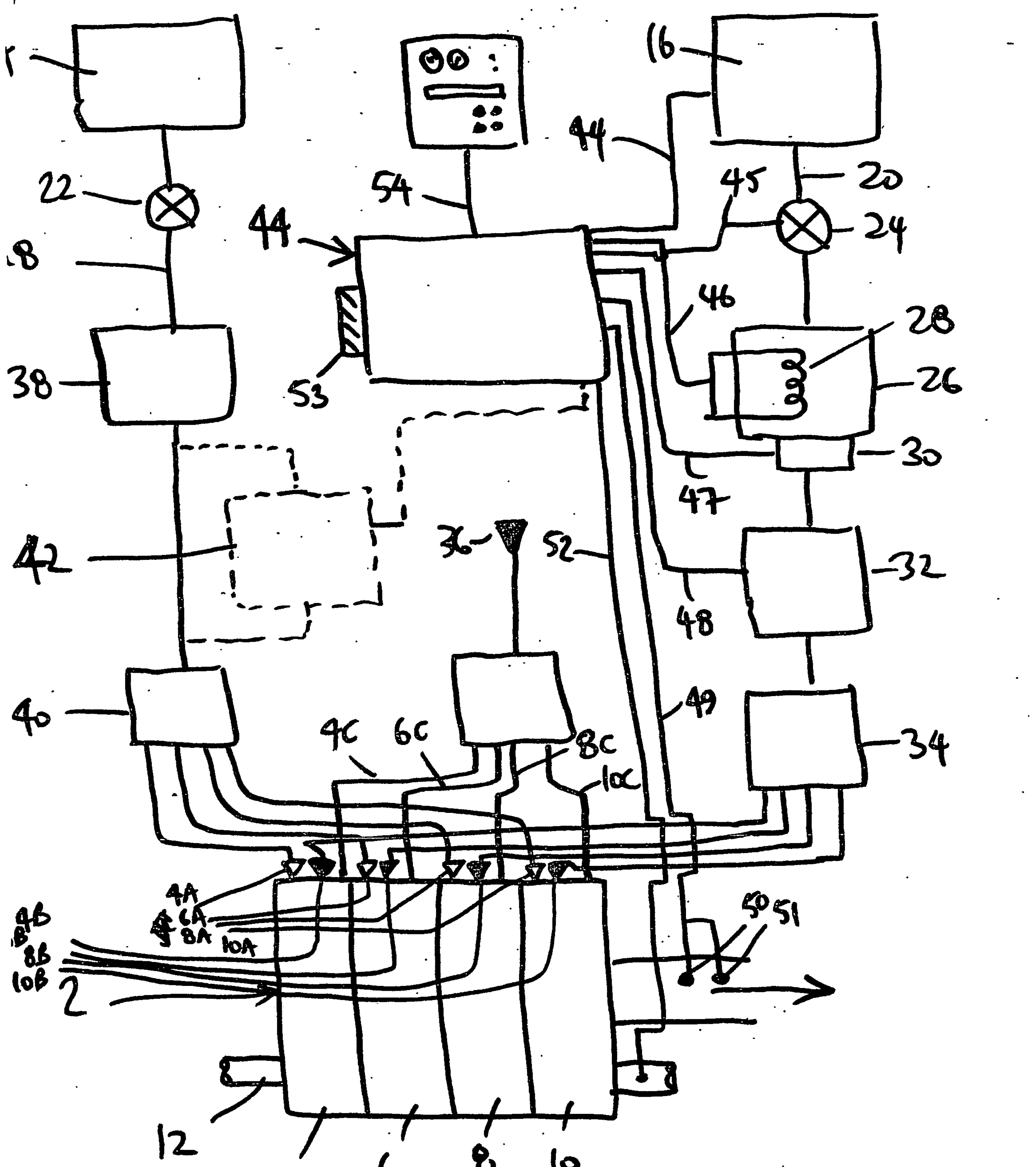

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FIG 1.